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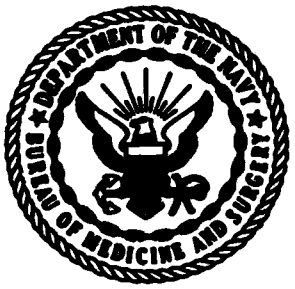

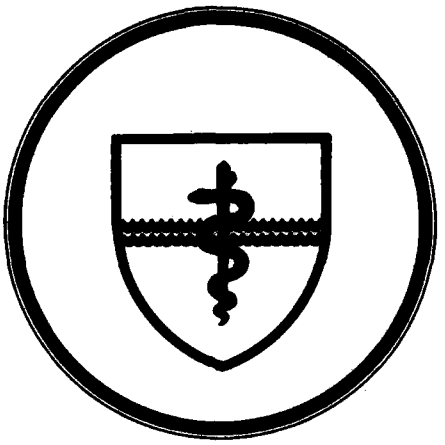

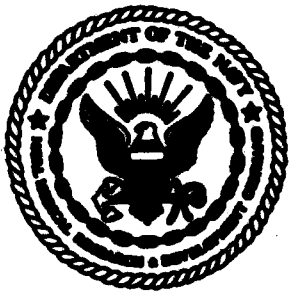

REPORT NUMBER 1055

ACCEPTABILITY OF LOW LEVEL WHITE LIGHTING IN THE SONAR ROOM AT SEA

by

David A. Kobus and S. M. Luria

Naval Medical Research and Development Command
Research Work Unit M0100.001-1023

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SUMMARY PAGE

PROBLEM

To evaluate the use of LLW lighting as a replacement for the blue or red lighting systems in the sonar control room.

FINDINGS

Seven out of the eight crews reported that working under LLW ambient lighting was highly preferred. They experienced less fatigue, better lighting for other tasks, and more importantly a decrease in visual recognition differential (NRD).

APPLICATIONS

The use of LLW lighting in the sonar control room and other control areas is highly recommended. The advantages gained with LLW lighting are numerous and will provide a better lighting environment for the future use of color displays.

ADMINISTRATIVE INFORMATION

This research was conducted as part of the Naval Medical Research and Development Command Work Unit M0100.001-1023 " Enhanced visual performance on submarines." It was submitted for review of 7 June 1985, approved for publication on 15 July 1985, and designated as NSMRL Rep. No. 1055.

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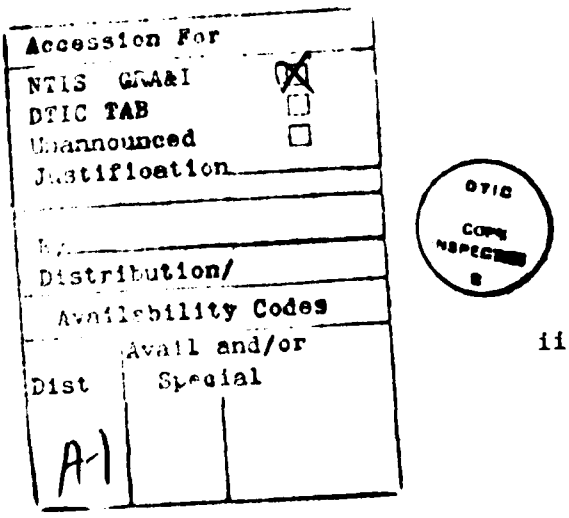
ABSTRACT

Eight submarine sonar divisions evaluated the use of low level white (LLW) lighting in their sonar control rooms. Seven of the eight crews highly preferred LLW and requested they be allowed to retain the filters. They reported experiencing less fatigue, better lighting for additional tasks, and most importantly a decrease in recognition differential (NRD). Recommendations are made to install LLW lighting in all submarine sonar control rooms.



Low level red lighting has traditionally been employed in all submarine control areas, including the sonar room. The original reason was to promote dark adaptation for the men in the diesel powered submarines that were required to surface or come to periscope depth regularly at night. With the advent of the modern nuclear powered submarine this need was all but eliminated. Yet, the red lighting system was retained primarily for dark adapting the periscope operator or in case of an emergency which could cause an unanticipated need to surface at night.

The continuing requirement for red lighting in submarines is controversial and particularly difficult to justify in the sonar room. When sonar information was primarily auditory, the type of lighting was unimportant, but today the information is presented visually as well. In fact, for the newest systems being designed the majority of the information is displayed visually.

Dissatisfaction with the red lighting system caused many sonarmen to alter the lighting within their work space. Some would extinquish all lighting, and some tried to go to a white light system in which the overhead lights in the vicinity of the sonar equipment were turned off. One submarine crew on their own initiative, utilized broadband blue lighting (1). Their idea came from the NAVSEA lighting manual which contains a chapter on blue illumination for radar system display consoles (2). The rationale for this lighting was that seeing would be improved if the visible spectrum were divided into halves, and the short wavelength (blue) used for general room illumination while the long wavelength (yellow) was used for the CRT. In the early trials of this procedure the division was achieved by placing a yellow filter over the CRT screen; this filter effected the split of the spectrum both by limiting the output of the CRT to long wavelengths and by not transmitting any of the blue ambient illumination to the CRT phosphor.

The initial trial of blue lighting was reported to have lowered recognition differential (NRD) and prompted an official test installation on another submarine (3). Word spread through the submarines in the local area, and since the filters were available in the GSA catalogues, many submarines changed over. Simultaneously, as part of a research project to determine the optimum conditions for watchstanding in sonar, NSMRL staff were surveying lighting conditions aboard local submarines (4). At the time of the survey several of the submarines had switched to blue lighting, and many of the men reported liking it. In addition, there were many complaints voiced about the red lighting. Before further evaluation could be made on the use of the blue lighting system, a message from COMSUBLANT (5) and COMSUBPAC (6) directed all submarines to convert their lighting systems in the sonar room to blue.

NSMRL continued its analysis of the popularity of blue over red and suggested four possible reasons. The first is the well-known psychological effect of improved morale which stems from any change that the participants perceive as being done for their benefit. The second is the fact from physiological optics that long wavelengths (red light) focus farther behind

the retina than light of shorter wavelengths and thus require more accommodation to see clearly at the same distance. This can be particularly uncomfortable for hyperopes (far-sighted individuals) or for older men who are utilizing most of their accommodative power under close viewing conditions and do not have the reserve for the long wavelengths. Third, blue lights, as installed in the sonar rooms, provide much more total light than do the red. Even if they measured the same with a photopic light meter (which they did not: blue was generally brighter), blue is much more effective in providing light at the low levels found in the sonar room than is red. Finally, there is the possibility that there is a real enhancement of visual sensitivity inherent in the use of blue lighting.

Some of the possible reasons for the shift to blue suggest a real advantage (i.e. decrease in NRD) to the use of blue, while others are relatively trivial (i.e. filter availability). In order to ascertain which one or ones were significant, a series of experiments was initiated, both in the laboratory and in sonar trainers at the Naval Submarine School.

A subjective assessment of blue, white, and red light in the Sonar Operational Trainers (SOT) by sonar crews of three submarines indicated general preferences for blue. There were, however, clear differences among crews of the different submarines, with one crew almost unanimously preferring red; this would seem to suggest a group psychological effect (7). Additionally, detection ranges on a passive broadband display were measured on the AN/BQQ-5 trainer. Two problems were done in the same session, one in red illumination and one in blue. Ten such comparisons revealed no difference between red and blue in the mens' ability to detect the target.

A third study of contrast sensitivity under controlled laboratory conditions revealed no differences between red, white, or blue ambient illumination at the low levels employed in sonar rooms (8). There was in fact no difference in contrast sensitivity between any of the various ambient illuminations; the levels were just too dim to affect visual performance, despite the fact that this is probably the most sensitive acuity measure that we have.

Thus there appears to be no contrast enhancement with blue as normally used in sonar. One or more of the other reasons must lie behind the preferences. Additional studies are going on, but it appears that the popularity of blue is a response to the real disadvantages of red. Low level white (LLW) would offer the same advantages as the blue over the red light, and some additional ones as well, such as having a less detrimental effect on dark adaptation plus the capability of using color coding.

The above conclusions led us to the investigation of LLW lighting to replace the red or blue lighting used presently. We proposed that LLW lighting would be the optimal type of illumination. We pointed out that few people know how to equate different colors for brightness at the mesopic or scotopic light-levels typically found in sonar rooms (9,10) using a photometer. When this was done properly, detection performance tended to be slightly better under the LLW light than under the blue lighting (11,12). Although performance was better under the white compared to the blue

lighting, the crews still demonstrated a preference for the blue lighting. Yet, preference and performance have not been shown to be related (11). In fact, the colors of illumination in which detection times were best were usually the least preferred (12). One of the evaluations (11) was carried out at the SOT. During this type of training many of the men operate only one piece of equipment rather then rotate as they normally do at sea. It appeared from the results that several men preferred the white from each sonar division, and we wondered if the results were operator dependent or dependent upon the equipment they were operating. In order to evaluate the effects of the lighting system properly, we initiated an evaluation of LLW lighting at sea.

METHOD

Subjects - Eight submarine sonar divisions evaluated the low level white lighting under patrol status. Appendix A provides a list of the submarines that participated in this study.

Procedure - Neutral density filters were manufactured by our laboratory to replace the blue filters on the lights in the sonar room. The filters were made to provide the same brightness as the original red filters. According to the nomogram published by Kinney (9) they gave approximately .1 ft candle of illumination as measured by a Pritchard photometer. Each sonar division operated under the LLW lighting for extended periods of time (six hours per watch cycle). Questionnaires were completed by each sonar watchstander at the end of the patrol, to evaluate the advantages and disadvantages of LLW lighting.

RESULTS

After the evaluation at sea, seven of the eight submarine sonar divisions highly preferred to work under the LLW rather than the blue or red lighting for extended periods of time. The crew which preferred the blue lighting commented that both the red and LLW lighting conditions were at a low level and promoted fatigue. In addition, several of the junior sonarmen commented that they preferred blue because it provided a "video arcade atmosphere". Selected comments of the advantages and disadvantages reported by the crews are listed in Tables 1 and 2 respectively.

The majority of the crews tested so highly preferred the LLW lighting system that seven submarines have requested to retain the filters until they are available in the GSA system. Many of the advantages reported by the submarine crews were similar to those initially given when the blue and red lighting systems were compared. For example, less fatigue, better light for other tasks, and most importantly a decrease in visual NRD. In addition, LLW provides a couple of advantages that were not possible under the blue lighting system. First, the brightness of the CRTs can be at a lower level which will help extend the life of the CRT. Second, it is easier to read and write under the LLW system. Lastly, there is little, if any, interference in the operators ability to color code. This last advantage is of critical importance owing to the recent advances in visual display technology which have increased the feasibility of using color CRTs for

TABLE 1. COMMENTS REGARDING ADVANTAGES OF LLW LIGHTING

1. It is much easier to work away from the sonar stacks on other tasks.

2. The LLW lighting makes things easily visable and less headaches are experienced.

3. It is easier to read material in sonar (qual. notes, tech. manuals, etc.).

4. It is easier to write and maintain sonar logs.

5. It is easier to use equipment with switches or controls that are not illuminated.

6. It is not necessary to ever go to a full white lighting mode to do other tasks which required more lighting then the blue or red could provide.

7. Several sonarmen felt that they were less fatigued after getting off watch.

8. LLW does not change the color of the CRT displays as it appears the blue and red light do.

9. LLW allows the operator to maintain CRT brightness to a minimum which will help extend the life of the CRT.

10. There was an increase in recognition differential (NRD) on the dimus traces more times then not due primarily to less fatigue.

11. LLW provided better color contrast on the control display console.

12. Light dimus traces were detected sooner and tracked for longer periods of time. (reported by two individuals)

13. Several of the sonarmen reported that they felt much better working under the LLW lighting in stressful situations.

TABLE 2. COMMENTS REGARDING THE DISADVANTAGES OF LLW LIGHTING

1. There is a tendency for the noise/distraction level to increase under the added light (noted also in the control room - people are quieter in the dark), especially in a small space like the sonar room.

2. The LLW lighting seems to promote fatigue.

3. When control room is rigged for red (prior to coming to PD) sonar must be rigged for black if the control/sonar door is open. (Sonar operators are required to cycle between sonar and control on <u>every</u> PD operation.

4. After an hour on the stack, small headaches and hurting eyes have been reported. This was reported as being especially true after using the passive broadband display during exercises that require close monitoring.

5. The transition from LLW to black or the no light condition is uncomfortable.

sonar displays.

DISCUSSION

Other areas such as the control room, radio, and ESM (Electric Surveillance Measures) are presently seeking a replacement for the red lighting. Luria and Kobus (13), have suggested that LLW may be used for a replacement for red even where there is a requirement for dark adaptation. Although red lighting is better for dark adaptation, the differences between red and LLW are small and are not of operational significance (14). Recently, a request was made by COMSUBLANT to test LLW lighting in the control room (15). This test proved to be highly successful (16) and has led to the request for future evaluations (17).

The previous evaluations of the broadband blue lighting were made on just two submarines before a decision was made to require the fleet to convert all sonar rooms to such a system (5,6). Yet, when they installed the blue light few submarines followed the guidelines of the NAVSEA lighting manual regarding the installation of the amber filters (2). Even so, blue lighting alone does not appear to "harm" sonar performance and may even provide some enhancement over the red lighting system by improving color contrast.

The disadvantages of LLW reported by the submarine crews of this study may be corrected. The primary objection was that when the door from the sonar room to the control room was opened during PD operations, the LLW "spilling out" of the sonar room was more annoying to the men in the darkened control room than the red had been. It now appears likely that the control room will also be converted to LLW due to the increased need for color coding and the need for fewer men to be dark adapated. In addition, LLW lighting has been recommended by the Trident Lighting Committee to replace red in the control room (18).

However, there is one additional problem that was observed while evaluating LLW in the control room (16). That is, areas that are peripherally viewed (such as the passageways) appear brighter under LLW than under red or blue illumination. This was distracting to control room observers and can be corrected by having filters of greater density in the passageways. The finding that LLW was more distracting than blue was quite surprising since peripheral vision of the retina is performed primarily by rods which are much more sensitive to blue.

Overall, LLW lighting appears to be the best choice for sonar and other control areas that require low level or mesopic lighting. A message has been sent by COMSUBDEVRON TWELVE (19) recommending that all sonar rooms be converted to LLW. COMSUBLANT has since requested the density requirements of the filters, and an A&I (Alteration and Installation)change is being prepared to make LLW filters available to the fleet (20).

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20. PHONECOM with COMSUBLANT, Jun 1985.

APPENDIX A

TABLE A. Submarines crews who participated in LLW evaluation.

USS U.S. GRANT (SSBN 631)
USS CITY OF CORPUS CHRISTI (SSN 705)
USS SHARK (SSN 591)
USS ALEXANDER HAMILTON (SSBN 617) - BOTH CREWS
USS WHALE (SSN 638)
USS BENJAMIN FRANKLIN (SSBN 640)
USS DANIEL BOONE (SSBN 629)

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Eight submarine sonar divisions evaluated the use of low level white (LLW) lighting in their control rooms. Seven of the eight crews highly preferred LLW and requested they be allowed to retain the filters. They reported experiencing less fatigue, better lighting for additional tasks, and most importantly, a decrease in recognition differential (NRD). Recommendations are made to install LLW lighting in all submarine sonar control rooms.

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